DISCOVERY

57(308), August, 2021

Analysis of Pre-Service Physics Teachers' Academic Achievement in Electromagnetism

Aina Jacob Kola✉**, Keith Roy Langenhoven**

To Cite:
Kola AJ, Langenhoven KR. Analysis of Pre-Service Physics Teachers' Academic Achievement in Electromagnetism. *Discovery*, 2021, 57(308), 597-607

Author Affiliation:
School of Science and Mathematics Education
The University of the Western Cape, South Africa

✉**Corresponding author:**
Dr. Aina, Jacob Kola;
School of Science and Mathematics Education,
The University of the Western Cape, South Africa
Email: akoja64@gmail.com

Peer-Review History
Received: 27 May 2021
Reviewed & Revised: 30/May/2021 to 03/July/2021
Accepted: 05 July 2021
Published: August 2021

Peer-Review Model
External peer-review was done through double-blind method.

ABSTRACT

The study is on pre-service physics teacher academic achievement in electromagnetism. The study obtained data from three hundred and eighty-eight graduated students of electromagnetism I and II from a College of Education. These achievement scores were that of students who graduated from 2011 to 2019. The authors employed three research questions to analyzing pre-service teachers' academic achievement in the research. The statistical analysis used was the Pearson moment correlation coefficient, Analysis of Variance (ANOVA), and descriptive statistics. Findings show a correlation between electromagnetism I and II, a no significant gender achievement gap, and weak students' achievement. Therefore, the authors believe good teachers' teaching method could be the best way to solve vulnerable students' academic achievement in physics, suggesting the shift of teaching paradigm to Peer Instruction Dialogical Argumentation (PIDAM).

Keywords: Academic achievement, Dialogical argumentation, Electromagnetism, Gender, Peer instruction

1. INTRODUCTION

Physics remains the bedrock of science and technology worldwide. However, students' academic achievement remains not impressive in all education levels in Nigeria (Okeke, 2019; Agommuoh & Ifeanacho, 2013). More problematic is the state of pre-service teachers' academic achievement in physics in colleges of education. The condition is not encouraging because these are prospective physics teachers expected to teach physics in our schools. Several studies in an attempt to solve the problem have not yielded positive results. The reasons responsible for this are many, as previous studies shows. Some scholars viewed physics courses as abstract (Bertrand, 2007; Adeyemo, 2010; Mulhall, McKittrick & Gunstone, 2001; Chang, 2007). For some, it is teachers' strategies of instruction (Wanbugu, Chiangeiywo & Ndirit, 2013; Malcolm, Hestenes, & Swackhamer, 1994; Watkins & Mazur, 2013; Crouch, Watkins, Fagen, & Mazur, 2007; Sokoloff, 2012). However, others attributed this to a lack of students' interest (Olufunke,

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2012; Garwin & Ramsier, 2003; Agbaje & Alake, 2014; Oon & Subramaniam, 2013; Hamelo, 2016).

The factors above and others might be responsible for low academic achievement in physics; however, the gender gap is another trending issue in physics education (Koul, Lerdpornkulrat & Poondej, 2016; Moore, Combs & Slate, 2012; Murphy & Whitelegg, 2006). Previous studies show male students do better in physics than females (Stephen, 2010; Aina, 2013; Gok, 2013; Jugović, 2017; Inyang & Josiah, 2016).

Gender issue in learning as a global discourse in physics is critical and the relationship between different aspects of physics. However, studies on the correlation between physics courses, such as optics and wave, electronics and electromagnetism, etc., are scanty. Knowing the relationship between two different courses in physics is critical in chosen more advanced careers. Guisasola, Zubimendi, and Zuza (2010) observed that electrostatic learning challenges might hinder more advanced physics topics. Similarly, students lack the understanding of using their knowledge in a physics course to explain another (Casperson & Linn, 2006). It thus implies that students' academic achievement in a physics course may influence performance in another.

The National Commission for Colleges of Education (NCCE) prescribes pre-service teachers' physics courses. NCCE is by law saddled with the responsibility of coordinating pre-service teacher programs in Nigerian Colleges of Education. Some of these courses are mechanics, heat, electromagnetism, waves, quantum physics, and others (NCCE, 2020). Studies show that most students have more challenges in electromagnetism than in other courses (Akanbi, Omosewo, Abdulraheem, & Ojediran, 2017; Constantinou, Papaevripidou & Hadjilouca, 2010; Sağlam & Millar, 2006; Roussel & Helier, 2012).

NCCE (2020) prescribed a research-based teaching paradigm that would enhance critical thinking and make physics students function effectively as teachers. This and previous studies suggest the need for a shift in the teacher's teaching strategies to more student-centered teaching engagement like peer instruction (Ouko, Aurah & Amadalo, 2015; Gok, 2012). Similarly, the dialogical argumentative instructional approach (Sampson, Enderle & Grooms, 2013). Integrating the two strategies to produce Peer Instruction Dialogical Argumentation Model (PIDAM) has effectively taught physics (Aina, 2017, 2020).

Given this, the current research investigates the students' academic achievement in electromagnetism for nine consecutive years. Electromagnetism I and II were the courses sampled for the study. These are the year one and two electromagnetism courses.

Purpose of the study

The specific objective of the study is to determine the pre-service physics teachers' academic achievement in electromagnetism. However, to achieve this purpose, the study shall investigate the correlation between the students' achievement in electromagnetism I and II. This objective is significant to help physics students and teachers know the relationship between the two courses. Additionally, the study aims to determine any gender difference in students' academic achievement in electromagnetism. Finally, the study shall use the Nigerian NCCE grading system to determine students' academic achievement in electromagnetism within these years.

Research questions

1. Is there any correlation between students' academic achievement in electromagnetism I and II?
2. Is there any significant gender difference between the students' academic achievement in electromagnetism?
3. What is the students' academic achievement in electromagnetism within the nine years of study?

2. MATERIAL AND METHODS

Research design

The research adopts a survey method using a documentary approach to collect data. It refers to the analysis of documents that contain information about the phenomenon a researcher intends to study (Mogalakwe, 2006). Research is conducted through official or personal documents as a source of information (Awoniyi, Aderanti & Tayo, 2020). The current study employed the official document from the college exam and record. The documentary approach could be explored in all fields, including business, anthropology, communications, economics, and education (Ahmed, 2010). Students' scores in electromagnetism I and electromagnetism II, graded in percent, are the study's data. These scores range between 0% and 100%.

Sample and Sampling Techniques

The sample population consists of three hundred and eighty-eight (388) physics students who graduated from a college education from 2011 to 2019. The first and second-year graduated students' scores were sampled because the two pre-service physics teachers do most of the electromagnetism work at these levels. There are different teacher training tertiary institutions in Nigeria. The college of education is one of these institutions, which the present study sampled. The scores of three hundred and eighty-eight

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

students who graduated from 2011 to 2019 were explored. The rationale for the sample was because the NCCE physics curriculum used is the same for this period. NCCE changes the College of Education curriculum periodically based on the needs in the education sector as it was changed in 2020. Physics students' population in Nigerian schools is always low compared to other science subjects (Okeke, 2019; Adolphus, 2019). Due to this, all students who graduated in these years (2011-2019) made available for the study were three hundred and eighty-eight students.

Research instrument

The research instrument for this study is a researcher self-designed Pro-forma to obtain students' scores in electromagnetism I and II from the college exam and record unit.

Validity and reliability

The data require no validation and reliability test because different physics education experts from various institutions had moderated the exam questions and the student's scores each year before publishing it in the exam and record unit of the college.

Method of data analysis

The data analysis used Pearson moment correlation coefficient, t-test, and descriptive statistics. The assumption of the equality of variances and homogeneity was tested and not violated. The Pearson moment correlation coefficient was employed to answer research question one; an independent t-test was used for question two because of the two independent variables (Electromagnetism I and II). Descriptive statistics was employed for research question three.

3. RESULTS

Research question 1: Is there any correlation between the first and second-year electromagnetism students' academic achievement?

Table 1

Correlation between Electromagnetism I and Electromagnetism II

		Electromagnetism I	Electromagnetism II
	Pearson Correlation	1	552
Electromagnetism I	Sig. (2-tailed)		.000
	N	388	388
	Pearson Correlation	552	1
Electromagnetism II	Sig. (2-tailed)	.000	
	N	388	388

Table 1 shows a strong positive correlation between electromagnetism I and II. The correlation coefficient is 0.64 as indicated in the Table.

Research question 2: Is there any significant gender difference between the students' academic achievement in electromagnetism?

Table 2

ANOVA Test of Between-Subjects Effects

source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	1668436.142	1	1668436.142	7970.729	.000
Gender	449.719	1	449.719	2.148	.144
Error	80797.677	386	209.320		

Table 2 shows a two-way mixed ANOVA conducted investigating the impact of gender and students' academic achievement in electromagnetism (Electromagnetism. I and II). There is no statistically gender effect because of the Sig. (2-tailed) value is 0.144, which is above 0.05. The assumption test of equality of variances and homogeneity was not violated because all the p-values were above 0.05. The Table indicates no significant main effect of gender $F(1, 386) = 449.719$, $p > 0.05$.

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Research Question 3: What is the students' academic achievement in electromagnetism within the nine years of study?

Table 3 *Academic Achievement of Electromagnetism*

Electromagnetism I		Electromagnetism II	
Score (%)	Frequency	Score (%)	Frequency
30.00	34	30.00	45
40.00	85	40.00	68
41.00	16	41.00	23
42.00	19	42.00	15
43.00	8	43.00	11
44.00	9	44.00	13
45.00	23	45.00	19
46.00	14	46.00	13
47.00	9	47.00	6
48.00	13	48.00	9
49.00	5	49.00	11
50.00	14	50.00	11
51.00	9	51.00	5
52.00	5	52.00	13
53.00	9	53.00	11
54.00	8	54.00	9
55.00	12	55.00	9
56.00	8	56.00	9
57.00	7	57.00	11
58.00	8	58.00	11
60.00	9	59.00	5
61.00	5	60.00	7
62.00	5	61.00	1
63.00	6	62.00	6
64.00	6	63.00	5
65.00	2	64.00	6
66.00	5	65.00	6
67.00	3	66.00	1
68.00	3	67.00	4
69.00	2	68.00	2
70.00	6	69.00	3
71.00	3	70.00	2
72.00	2	71.00	5
73.00	1	72.00	1
74.00	3	73.00	2
75.00	3	74.00	1
76.00	1	75.00	1
77.00	2	76.00	1
78.00	2	78.00	2
79.00	2	79.00	1
82.00	2	80.00	1
		81.00	1
		84.00	1
		87.00	1
Total	388		388

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The Table shows poor students' academic achievement in electromagnetism I and II. A significant number of students' scores is between 40% and 50%, majority of these students scored 40%. A few students scored above 60%. Nigeria grading system of the National Commission for Colleges of Education (NCCE) in Table 4 shows this is a poor achievement in electromagnetism within the nine years of study.

Table 4

NCCE Student Grading System

S/n	Grades	Interpretation (%)	Points
1	A	70-100	5 (Distinction)
2	B	60-69	4 (Credit)
3	C	50-69	3 (Merit)
4	D	45-49	2 (Pass)
5	E	40-44	1 (Low pass)
6	F	0-39	0 (Fail)

Source: NCCE (2020)

Table 4 is the grading system for Nigeria colleges of education. Most students in this study had low pass grades in electromagnetism I and II. Only 27 students have a distinction in electromagnetism I, and the number drops in electromagnetism II. Given this, the students' achievement in electromagnetism for the years under consideration is weak. In the Nigerian system of education, this achievement is not expected from prospective physics teachers.

4. DISCUSSION

Understanding the correlation between physics courses (electromagnetism, wave, heat, optics, electronics, mechanics, etc.) is vital for teachers and students. For instance, electromagnetism II is a continuation of electromagnetism I. Therefore, there should be a significant relationship between the two courses. Determining the correlation between the two courses is essential in the Nigerian Colleges of Education physics curriculum. A student must pass one before such a student is allowed to register for the second. All physics teachers must possess this correlation knowledge due to their unique position in physics education. This study's outcome is critical to physics education because a physics teacher is indispensable for the effective learning of physics (Dupe, 2019) in any nation. The lack of this understanding has been responsible for most failures in physics education. Ibibo and Francis (2017) observed that a lack of basic algebra knowledge makes physics students fail problem-solving physics tasks. The positive correlation between electromagnetism I and II in the current study may explain why Wenno (2015) concluded a linear correlation between mathematics and physics. Mathematics is critical to the understanding of electromagnetism. According to Albe, Venturini, and Lascours (2001), students have problems understanding some concepts in electromagnetism with mathematical backgrounds. The electromagnetism I and II curriculum in Colleges of Education is more problem-solving, thus the correlation between the two. This result may also explain why most students are not pursuing an advanced physics career after graduating from Colleges of Education with low grades.

The gender achievement gap in science learning has been a long debate in academia with no consensus (Kristyasari, Yamtinah, Utomo & Indriyanti, 2018; Aina, 2017). There are studies with evidence of gender gap in academic achievement, while some argued there is no gap.

However, the outcome of this study on gender-related achievement in electromagnetism is consistent with Moore, Combs, and Slates (2012) that the gender academic performance in the Advanced Placement physics exam is not significantly different. Similarly, Alao and Abubakar (2010) contended that there is no difference in the physics academic performance of male and female students in a Nigerian college of education. In a related study, Day, Stang, Holmes, Kumar, and Bonn (2016) averred that there is no evidence that female students are less capable of learning physics than male students.

Conversely, the current study is not the same with many authors as they suggested a significant gender gap in achievement. Some scholars believed that males do better in physics achievement than females (Aina, Akintunde, 2013; Stephen, 2010; Musasia, Abacha & Biyoyo, 2012). For Gok (2013), boys perform better than girls only in the problem-solving aspect of physics. Another bloc of scholars argues that females are better at physics achievement than males (Acar, Büber & Tola, 2015; Adeoye, 2010; Jugović, 2017). The gender gap in achievement is not only in physics, but Abdullahi, Abubakar, Abubakar, and Aliyu (2019) averred that it is

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

generally in science and technology education. The gap in physics may not be unconnected to the low enrolment of girl-child in physics, as observed by Sax, Lehman, Barthelemy, and Lim, 2016; Wanbugu, Changeiywo, & Ndiritu, 2013).

In light of the various authors cited above and the outcome of the current study, it's clear that there is no consensus yet on the issue of gender academic achievement in physics. Therefore, the discourse is ongoing and depend on the empirical finding of different author or scholar.

As revealed by this study's finding, the low achievement in electromagnetism I and II supports previous empirical findings (Bertrand, 2007). Studies show that students have challenges learning and comprehending electromagnetism in schools (Constantinou, Papaevripidou & Hadjilouca, 2010). According to Dori and Belcher (2004), because electromagnetism abstract, its learning is challenging. Akanbi, Omosewo, Abdulraheem, and Ojediran (2017) attributed misconception to pre-service teachers' challenge of understanding concepts used in electromagnetism. This result may also be attributed to teachers because Rochowicz, Karbowski, SłuŜewski, and Karwasz (2010) posits that electromagnetism is challenging to teach.

The finding of this study on students' academic achievement is consistent with Lacambra (2016), Mekonnen (2014), Shamim, Rashid, and Rashid (2013). This findings' outcome is problematic because the results sampled here are those students who have graduated some years ago. This is because many of them are in schools teaching physics which they have low achievement. This is one significant reason poor academic achievement persists in Nigerian schools. Several previous studies indicated poor academic achievement in physics. Poor students' academic performance in physics is a source of concern to stakeholders in education (Dupe, 2013). The students' low academic achievement at the Nigerian secondary school level has been a government concern (Onah & Ugwu, 2010). According to Inyang and Josiah (2016), physics is challenging to teach and learn. The issue of low academic achievement and challenges in physics learning is not limited to Nigerian schools; it's a global problem (Asamoah & Aboagye, 2019; Wartono, Batlolona & Sholikhan, 2017; Guisasola, Cock, Kanim, Ivanjek, Zuza, Bollen & Kampen, 2014). However, the current findings are worrisome because these are pre-service teachers who are supposed to teach physics in our schools. Given this, a shift of paradigm of instruction in physics education is required as a practical solution among many.

The need for a paradigm shift

Findings of this study and previous studies require the need for the shift of teaching paradigms in physics. Previous studies attributed low achievement in physics to teachers' teaching methods (Crouch, Watkins, Fagen, & Mazur (2007; Wanbugu, Chiangeiywo & Ndirit, 2013; Watkins & Mazur, 2013). Quality teachers who are competent in using a research-based paradigm to teach physics are critical in all education levels. Given this, the study suggests the PIDAM framework solves the low students' academic achievement in electromagnetism as a tested framework (Aina, 2017).

The framework integrates the Peer Instruction (PI) with a Dialogical Argumentation Instructional Model (DAIM). PI is an instructional strategy where students study in groups of two or three against the conventional methods of studying alone (Alvarez-Alvarado, Mora & Cevallos-Reyes, 2019). According to Passeri and Mazur (2019), PI is an interactive teaching and learning process between peers. Dialogical argumentation is about mastering discourse skills such as claim, evidence, warrant, and conclusion (Kim & Roth, 2018).

A dialogical argumentation-based classroom provides learners environments to express their views freely. Students interrogate any scientific information given by the teacher before reaching a consensus through harmonious understanding or cognitive harmonization.

The two paradigms focus on active and student-centered interactive learning engagement. Therefore, the Peer Instruction (PI) merged with Dialogical Argumentation Instructional Model (DAIM) examines how students' comprehension is enhanced when supported with peer discussion.

After the first voting in PI, pre-service science students formed different opinions in their minds regarding the concept under discussion. When peer discussion began, each student started to convince their neighbour regarding the idea already created in mind through Argumentation. According to Nielson, Hansen-Nygård, and Stay (2012), the students' first answer enhances more arguments on the concept presented during the discussion, which students are likely to reach a consensus.

PIDAM is an instructional framework creating cognitive teaching and learning situations through which peer discussion could be valued, as in Figure 1 below. The framework allows group discussion and group leaders' presentation to strengthen understanding before the final revised answer. As the group leader makes a presentation, any class members of different views can, through dialogical argument, query the group answer, resulting in a consensus or alternative perspectives. After the revised final solution, the framework indicates that the following step is a new or revised concept. The students' comprehension of the concept is consequently evolved and regarded as highly acceptable by the group. The instructor/teacher can decide to repeat the teaching or move to the next topic or concept.

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

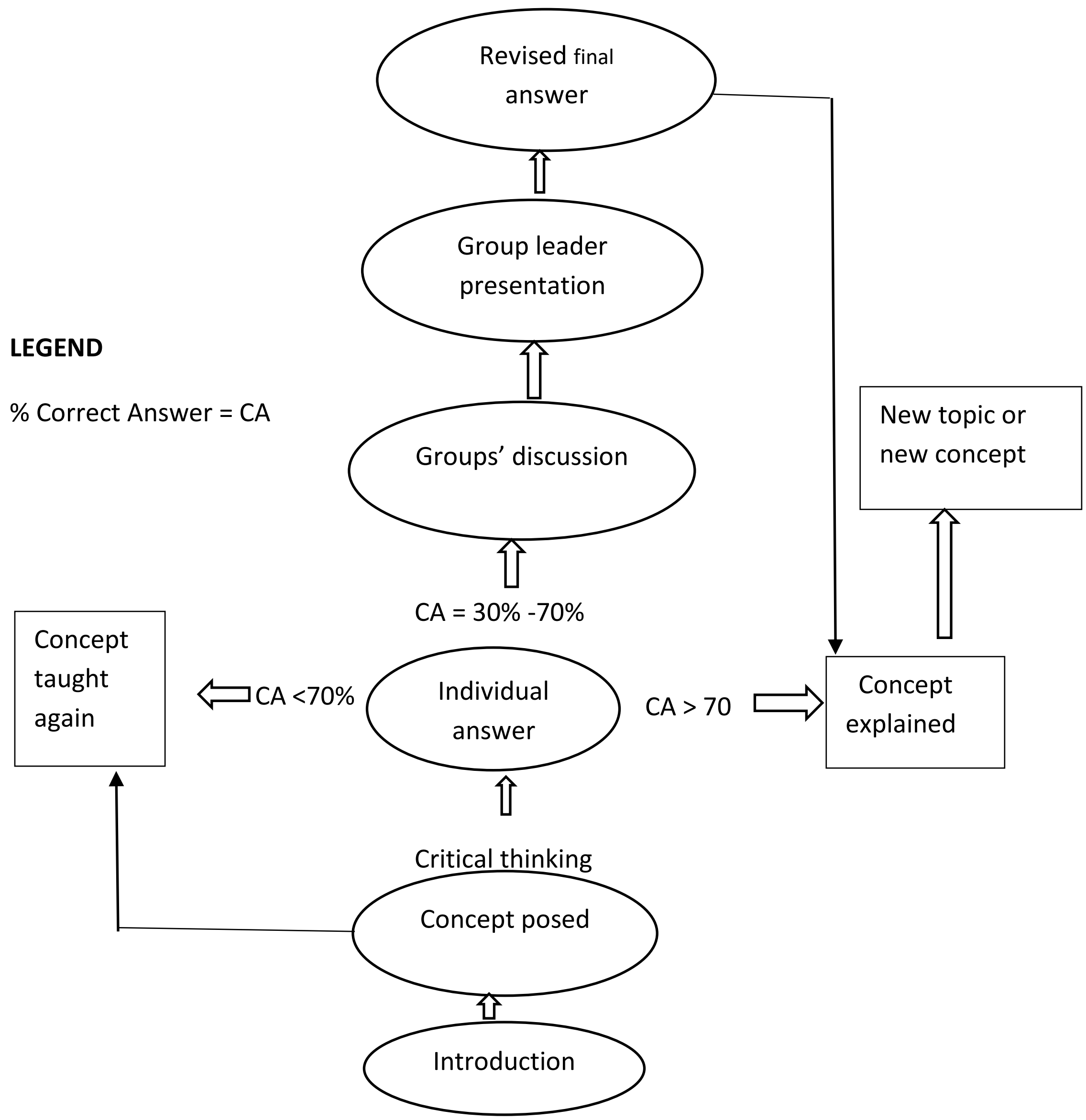

Figure 1. Peer Instruction Dialogical Argumentation Model (Aina, 2017)

The framework has unique features that make it a robust science teaching paradigm: social interaction and critical thinking. The absence of the two constructs in the conventional paradigms is the significant reason for low physics achievement (Schreiber & Valle, 2013; Rodrigues & Oliveira, 2008; Saingan & Lubrica, 2008; Dori & Belcher, 2004). The framework highlighted a period of critical thinking after the teacher introduces the concept to be learned. This is a crucial period in learning because, according to Jones (2007), critical thinking is a set of cognitive skills that involves problem-solving. For Visser, Visser, and Schlosser (2003), critical thinking requires an adequate understanding of the subject under investigation.

The PIDAM creates room for students' interaction. According to Schreiber and Valle (2013), learning is a social and collaborative activity that allows students to construct meaning and interact with peers and teachers. The submission of Valle is underpinned by social constructivism theory. According to Kim (2001), the theory helps learners construct knowledge through their interactions with colleagues and the environment during learning.

The PIDAM is situated in constructivism theory and constructive controversy theories. Constructivism stands on the importance of knowledge and repertoires an individual brings to the learning context (Garbett, 2011). The PIDAM holds that students have personal knowledge brought into learning (Cognitive) and knowledge acquired through the social interactions during learning (Social). The knowledge helps students to contribute to the class discourse through dialogical arguments underpinned by constructive controversy theory.

Constructive controversy theory believes that someone's idea, opinion, and conclusion may not be compatible with another's

opinion, view, and judgment, but the two seek to reach a consensus to solve a problem (Johnson & Johnson, 2003). It is never a debate or a separate way of resolving controversy in learning. It is joint learning which allows individuals with different conflicting opinions to agree on consensus based on reasoning and evidence (Johnson & Johnson, 2007). Constructive controversy is based on the understanding that a complex problem could be solved to create a discussion and controversies about the issue (Daniels & Cajander, 2010).

The robust feature of PIDAM is the social interaction and students being able to engage in meaningful discussion to clear wrong conceptions in science learning. Most of the learning strategies explored by physics teachers do not permit students' interaction and conversation during learning. Electromagnetism consists of many abstract concepts challenging for students to understand (Chang, 2007; Bertrand, 2007) through most conventional teaching paradigms. PIDAM allows students to collaborate during and after learning; it enhances social interaction among learners and the teachers. According to Hursts, Wallace, and Nixon (2013), social interaction enhances students' learning. Studies show that students learn best when they have the opportunity to teach themselves than when they are led by the teachers (Moore, Warners & Jones, 2016; Chowdhury & Rashid, 2014).

5. CONCLUSION

The study sampled three hundred and eighty-eight (388) pre-service physics students' scores in electromagnetism who graduated from a college of education from 2011 to 2019. The electromagnetism courses explored in the study were those offers in the first and second year by students. The findings revealed that there is a positive correlation between the first and second-year electromagnetism courses. This may likely explain why most students could not pursue advanced physics careers after graduating from a College of Education as physics graduates. Also, the gender achievement gap in electromagnetism is significant, and low-level students' academic achievement. These findings conform to several previous studies on gender and students' achievement in physics in Nigerian schools and the poor students' academic achievement in physics. The implication of these findings on physics education calls for shifting the physics teaching paradigm to research-based strategies. Given this, the authors advocate for the PIDAM framework to enhance students' academic achievement in physics.

RECOMMENDATIONS

Because of the importance of all aspects of physics to society, the following recommendations are imperative:

- Researchers could replicate this study for all other physics fields such as optics, electronics, mechanics and properties of matter, etc.
- Physics teachers should always be sensitive to gender-related issues in a physics classroom.
- The government should stop employing teachers who are not adequate in physics content knowledge in our schools

Ethical issue

The researchers obtained proper permission from the physics department's appropriate authorities to use these scores for the research. The data shall be used only for this study's purpose without sharing with any individual or organization. For confidentiality and anonymity, the name of the college was not be mentioned anywhere in the research.

Conflict of interest

The Authors have no conflicts of interest that are directly relevant to the content of this clinic-pathological case

Financial Resources

There are no financial resources to fund this study.

Data and materials availability

All data associated with this study are present in the paper.

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